Is the energy crisis accelerating the transition to renewable energies?

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Abstract

The thesis aims to form a compelling argument for the significant impact of the energy crisis on the financing and implementation of renewable energy sources. By exploring various policies and reports, the thesis seeks to shed light on the role played by the energy crisis in spurring the accelerated adoption of renewable energy technologies. The examining of policies such as the Inflation Reduction Act in the United States, the “Fit for 55” package, Green Deal and REPowerEU in Europe, and ambitious energy targets set worldwide, contribute to the assertion that the energy crisis created an urgency for governments to take action towards clean energy sources. The research in this thesis draws upon comprehensive publications such as the World Energy Outlook by the International Energy Agency (IEA) and reports by the International Renewable Energy Agency (IRENA), in addition to an array of publications. The findings in the research based on a range of perspectives and sources strengthen the thesis’ argument, and offer insight into the funding, implementation and governmental actions accelerating the shift towards renewable energy technologies.

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Introduction

Energy prices have risen to their highest levels seen in decades. Energy is a key driver for societal development and the base of increasing living standards, which is why the crisis has such strong repercussions in society. The recent elevation in price can be traced back to the period most effected by Covid-19, most of the year of 2020. During this period, the world stopped much of traffic and industry for some months, which led to a rapid increase in energy use in the following year as countries made efforts to make a fast economic recovery at the global scale. The invasion of Ukraine of February 2022 exacerbated the already stressed energy and economic systems into a global energy crisis. After this, the energy prices soared, especially gas had record highs following the invasions, and oil saw the highest levels since 2008. According to the IEA, this crisis has sparked an unprecedented momentum for renewables (IEA, 2022f). The high energy prices have led to high inflation. The situation is financially unsustainable for many countries and households. The crisis has had more dramatic impacts on economy and society than the pandemic (IEA, 2022e).

The current situation can serve as a pivotal moment in the transition towards renewable energy sources, among other important steps towards net-zero emissions systems, largely due to the unprecedented response from governments worldwide. The writing of this thesis has drawn upon well-known global publications such as World Energy Outlook produced by the International Energy Agency (IEA), reports written by the International Renewable Energy Agency (IRENA), along with numerous comprehensive reports, articles and governmental resources. The urgency created by the energy crisis has spurred governments worldwide to pursue deployment of cleaner energy sources. This thesis examines a range of policies, including the Inflation Reduction Act in the United States, the Fit for 55 package and REPowerEU in the European Union, and ambitious clean energy targets in China. By exploring these policies, this thesis seeks to shed light on the financing and implementation of renewable energy sources, as well as governmental actions towards cleaner energy sources. *The aim of the thesis is to establish a strong case for the role played by the energy crisis in spurring the accelerated adoption of renewable energy technologies.*

There have been earlier energy crises, like the oil shocks in the 1970s, which offer insight and parallels that can be drawn to the current situation. Today's crisis involve multiple energy sources, most notably the fossil fuels, whereas the 1970s price shocks were mainly limited to oil. The global economy was highly dependent on oil at the time, while being less reliant on other fossil fuels compared to the present day. The global economy has become more interlinked as the time has gone which is why the current crisis can be referred to as the first energy crisis at the global scale. The global energy market has been highly reliant on fossil fuels and a secure supply from gas and oil-exporting countries, including member countries of the OPEC, the United States, and most notably, it has created a reliance on Russian fossil fuel supplies. This vulnerability in the global energy system has been particularly exposed in the years 2021 and 2022 as the energy and economic systems have

been strained in a state of recovery and high demand, which was intensified after the invasion of Ukraine. These conditions have created a situation which can be called a global energy crisis. This poses additional challenges for implementation of the energy transition envisioned on a global scale following the Covid-19 pandemic. However, as this thesis will highlight, the proactive measures taken to tackle the energy crisis, along with international cooperation efforts to enhance energy security, have created a favorable environment for an increase in integration of renewable energy sources.

The energy sector has long been slowly transitioning away from fossil fuels. Although the global energy system has been highly reliant on fossil fuels, climate policies have received some blame for the extent of the crisis. On one hand, there have been decreasing investments in the fossil fuel industry, which could be a contributing factor to the energy demand-supply gap. Based on this, investments in the fossil fuel industry might seem like a reasonable solution to the energy crisis. However, on the other hand, one could point to the fact that a greater supply of green technologies and energy sources have dampened the effect of the crisis and protected consumers, mitigating some of the pressures on energy prices. Indicating that renewable energy sources have had a positive effect on mitigating the impact of the crisis, highlighting the need for upscaling investments in renewable energy technologies to boost energy security with a diverse and sustainable supply. Some of the benefits of renewable energies compared to fossil fuels in addition to addressing environmental concern, include opportunities for decentralized energy production, energy independence and job creation. These advantages emphasize the need to expand investments in this sector in times of economic, environmental and geopolitical concerns. Policymakers worldwide recognize the potential of renewables and are taking steps towards transitioning the energy sector to these cleaner energy sources to promote resilient and sustainable future (IEA, 2022e).

The world is currently in an energy crisis of unprecedented scale, which has made energy security a main concern. The energy crisis is characterized by growing energy demands, inflation, dwindling fossil fuel reserves and increasing concerns for environmental degradation and climate change. This text will start off with a chapter on the energy crisis, to look at the problem at hand and create a contextual understanding of the vulnerabilities connected with high reliance on fossil fuels in today's energy systems.

The second chapter will shift focus to the transition to renewable energy sources, their extent and future potential. The latter chapters discuss whether the energy crisis accelerate or deaccelerate the energy transition, considering the multidimensional aspects of energy security, economic factors associated with the cost and investments, and, how this shapes policy decisions. This structure will aid the reader to better understand why there is a need and urgency to transition away from fossil fuels and look at renewable energies as a solution to address the crisis and increase energy security. The text will explore and discuss both

sides of the argument, exploring the potential impact of the energy crisis on the transition to renewables. It will consider arguments suggesting that the energy crisis might slow down the transition and arguments for the opposite, supporting the notion that the energy crisis actually will accelerate the transition to renewables. Lastly, there will be a conclusion of key findings and arguments presented throughout the text, providing compelling reasons for why the energy crisis serves as a catalyst for accelerating the energy transition.

Energy crisis

The importance of energy

Both “energy” and “crisis” are terms that have been frequently used in literature and in the media the last two years. The term “energy” has wide historical roots in various scientific disciplines. Among them, in the history of physics, it is connected to the capacity for doing work, which can be somewhat diffuse and tells us little in the social sciences. The sciences of physics and thermodynamics operate with the notion that energy cannot be lost or created, it just changes form, while in social sciences and in modern society, energy is commonly referred to being produced, consumed or wasted. One could say that contrary to physics and thermodynamics, in the realm of social sciences, particularly pertaining to political disciplines, energy sources acquire significance and societal importance related to their association to political, economic and social activities (Zimmermann, 1951).

The societal impact on the value of energy sources can be illustrated by looking at the historical significance of oil. The black “rock oil” have long been a familiar substance. Throughout ancient times there have been numerous applications for oil in the fields of medicine, pharmacy and agriculture, and it has even been utilized as a literal weapon and for religious purposes (Högselius, 2019). However, it was not until the second half of the nineteenth century, during the industrial revolution, that oil gained the substantial recognition as a crucial energy resource. During this period, there was an uptake in industrial activities, which related strongly to the demand of oil. The substance provided a superior energy source compared to coal and wood as it is higher in energy density, easier to transport and cleaner combustion compared to the other utilized fuels at the time (Högselius, 2019).

In the form of kerosene and later gasoline, oil provided efficient fuel for industrial machines and lighting sources which gained popularity throughout the century. The development of the combustion engine happened at the same time, revolutionizing the transport sector with oil-powered engines that replaces the traditional freight such as horses and steam powered engines. Other usages for oil were lubrication for the machineries and the development of petrochemicals such as plastics and synthetic fibers. From the mid 1800s, oil became much more than non-energy related “rock oil”, as it gained its significance as an immensely popular energy source due to the political, economic and social activities that constructed its

value in society. The energy system is deeply rooted in the dynamics of the societal realm, shaped by the perceived value of the energy sources. The failure or success of a particular energy resource can appear arbitrary and influenced by coincidences, as with innovative technologies, the process depends on critical support for the idea among politicians, capitalists and the general public. Moreover, energy sources are debated, where the risks and benefits are carefully weighed against one another (Högselius, 2019).

Over the last two centuries, the economic system has become increasingly intertwined with the global market for fossil fuels. The introduction of energy resources as commodities of international trade heightened the economic importance of the resources such as coal, oil and gas. These resources are assigned market values, which most likely incentivized their large-scale extraction as fossil fuels are costly to extract. Had the resources not had this high value to society, it is plausible that a considerable amount of fossil fuels would remain untouched, deep beneath the Earth's surface and seabed (Högselius, 2019). The interconnectivity between fossil fuels and the global economic system stands as a major driving force behind the widened scope of the ongoing energy crisis. The access to fossil fuel has established itself as a crucial pillar in modern society. On background of this, the thesis argues that renewable energy sources serve as buffers against disruptions in energy access and availability, providing a higher degree of energy security and economic stability than the fossil fuels.

What is an energy crisis?

The lack of energy access combined with high demand have led to high energy prices, which challenge the modern way of living to the extent that we call it a crisis. The growing reliance on energy and electricity amplifies the urgency to respond to the situation. The high dependence on energy creates a lot of opportunities and developments, however, this becomes a vulnerability when access is disrupted or limited. The consequences of disturbances in the energy supply are far reaching, transcends borders, and affects nations, economies, businesses and daily lives.

Crises are often understood as unwanted changes from a situation which is perceived normal, to a degree of uncertainty which cannot be solved through ordinary solutions (Engen et al., 2017). For this reason, extraordinary action and organization is required. Therefore, a crisis often represents a critical turning point or time of danger. The definition made by Rosenthal and his colleagues translates well to the definition of an energy crisis, as they define crisis as: "A serious threat to the basic structures or the fundamental values and norms of a social system which under time pressure and highly uncertain circumstances necessitates critical decisions" (Rosenthal et al., 1989, . 10). This definition accurately reflects the notion of what an energy crisis is, as it underscores the profound impact energy

crises has on social systems, independent of time and space, as well as grasping the urgency and critical decision-making.

There are numerous definitions of what a crisis is or can be, as the conditions which are present before and during a crisis can vary widely. The different definitions emphasize various characteristics as crucial to understand the basic features of what defines a crisis. Many define each crisis as being a unique phenomenon while others highlight that while crises are distinctive, they can also be recognized by a set of common features. The general characteristics of a crisis might be the perception of a threat, confusion, time pressure, uncertainty, challenges with finding a resolute, and lack of control. Furthermore, there can be issues with communication and information sharing, as both too little and too much of irrelevant information contribute to complicate the situation further. Other definitions point out the importance of the other features such as perspectives on societal safety, and emphasize the demarcation of time and space as well as obstruction of societal functions, together with the mention of interruption of social systems which Rosenthal and colleagues also highlight (Engen et al., 2017; Rosenthal et al., 1989).

Based on the definition written by Rosenthal and colleagues (1989), incorporated with other perspectives on the subject, energy crisis can be defined as an unwanted occurrence in relation to energy and energy security, threatening structures, values and societal functions and systems, with a need for critical and urgent decisions made under a great deal of uncertainty. Energy crises can occur when the demand for energy exceeds the supply, which lead to energy shortages that threaten the energy security and functions of core systems and structures in modern society. Affordability of energy and secure access are major issues for decisionmakers, including policymakers, communities and business leaders. Shortages can result in high energy prices, blackouts and disrupt economic stability, all of which have proven to be the case in the ongoing energy crisis. The high reliance on energy will further increase in the widespread process of electrification which is already taking place and adds to the societal vulnerability to disruptions in energy supply. Based on the surging electricity demand, governments must reassess their energy supply strategies, and have particularly moved away from reliance on liquified natural gas the past year during the energy crisis. Governments increasingly acknowledge renewable energy technologies as viable solutions to meet the growing energy demand, a topic that will be further highlighted in subsequent sections of this thesis.

It is important to note the difference between energy and electricity. Energy refers to the total energy consumption or production for electricity, heating and transport. Electricity is a component of the total energy production. Different energy sources attribute more to some energy components than others. For example, renewable energy sources and nuclear energy contribute more to electricity than it does to transport and heating. In fact, the two sources account for 36,7% of global electricity production, but only 15,7% of the total energy mix

because transport and heating at the global level rely more heavily on fossil fuels (Ritchie et al., 2022). This text will mostly refer to energy, energy consumption and energy crisis, rather than electricity because energy entails a broader scope than electricity, although, there will be some mention of electricity specifically. Energy has been preferred as a term for this text especially for the inclusion of fossil fuels and the overall energy prices.

The energy transition is perceived as a process beyond the sole focus on electricity production. While the generation of clean power and electricity production constitutes a significant aspect of the energy transition, it is recognized that sectors such as transportation and heating are major contributors to elevated energy prices associated with the energy crisis, with their reliance on fossil fuels as these sectors pose challenges in the conversion to electrification, and the decarbonization process. The research utilized in this thesis has been based on the broader notion of energy, encompassing aspects beyond electricity to grasp the comprehensive transformation that needs to occur. This understanding translates to the acceleration of the transition to renewable energy sources, as it acknowledges the need for deployed renewable energy sources and technologies across various sectors, such as heating and transport, in order to mitigate the effects of both the energy crisis and climate change.

Scope of the crisis

Bottlenecks in energy supply and energy shortage have long been an impediment to global economic growth. The biggest energy crises prior to the current one, are the OPEC oil embargo of 1973 and the 1979 oil crisis. In the former instance the oil prices rose by 350%, causing ripple effects that worsened economic conditions with mass layoffs, inflation, and stagnation. In the latter embargo of 1979, there was a drop in production following the Iranian Revolution (Yasmeen et al., 2022). According to the International Energy Agency, oil accounted for just over 46% of the total energy supply globally in 1973, constituting a significant share of the energy mix at the time. For reference, the percentage of oil in the total energy supply has remained fairly high, with it being 30,9% in 2019. Showing that the world has maintained a high reliance on this substance for energy generation since the 1970s, although, it has been high since the industrial revolution (IEA, 2021a).

The fossil fuel embargoes, also referred to as energy crises, were faced during the 1970s. These embargoes combined, led to the ‘70s being recognized as a period with negative economic growth linked to energy shortages. This type of energy crisis has been the type that the world has been most familiar with, which represent a historical context that differ from the recent energy crisis. A major distinction lies in the fact that the oil shocks of the 1970s stemmed from embargos of Arab oil exporters. On the other hand, the contemporary energy crisis is characterized by a combination of Russian withholding of supplies and a pervasive self-imposed embargo, as a result of a widespread international boycott driven by solidarity with Ukraine. Another difference between the energy crises is the ability to

cooperate amidst the present one, as opposed to the transnational conflicts that occurred alongside the ongoing wars in the 1970s. The current crisis presents new opportunities for collaborative efforts and diplomatic solutions to address the energy security concerns and achieve the collective goals related to sustainable development. Furthermore, contrary to the previous energy crises, the current one has multiple dimensions including, not only oil, but also gas, as well as electricity, food security and climate concerns. The solutions to these issues are multi-faceted and complex. Rather than simply reduce reliance on a single energy commodity, as was the case during the 1970s, the response to the contemporary crisis requires a restructure of the whole nature of the energy system, all while maintaining energy security through affordable and secure provision. Moreover, countries are likely to see the high energy prices as an incentive to implement policies that accelerate energy transitions, as has been done in the EU with the REPowerEU Plan and in the United States (US) Inflation Reduction Act. The crisis also incentivize an advancement of innovation, such as happened in the 1970s as a response to the oil price crisis at that time (IEA, 2022e).

The current energy crisis appears to be more intense than the previous ones, as the repercussions and challenges seem to be larger both regarding complexity and in the worldwide magnitude. The market was affected by multiple pressures ahead of Russia's invasion of Ukraine, like the global industrial recovery from the Covid-19 pandemic, difficult weather conditions in various locations, and geopolitical tensions. In addition, the EU reduced the number of carbon allowances in the EU Emissions Trading System, contributing to raise the prices of carbon emissions (European Commission, 2021). Furthermore, there has been maintenance work done on supply pipelines, coupled with reduced investments in oil and gas from exporting companies and nations. There have not been sufficient funds towards the fossil fuel industry to meet demand, in parallel to limited deployment of alternative energy sources such as renewable energy. Additionally, nuclear power plants have needed to shut down during this period due to maintenance requirements associated with corrosion (McWilliams et al., 2022).

The invasion of Ukraine exacerbated the economic situation. Russia began withholding gas supplies already in summer 2021, and did not refill Gazprom-owned storage sites in the EU after this (McWilliams et al., 2022). Russian gas has been a major source of energy for European energy consumption, responsible for a quarter of the energy consumed in EU in 2021 (IEA, 2022h). In response to the invasion, the United States and the EU placed sanctions on Russia and countries importing Russian supplies, with the objective of declaring intentions of phasing out Russian gas imports and ultimately eliminate the dependence on their supplies. After the invasion in February 2022, Russia manipulated the European natural gas market by using what remaining supplies they exported to Europe as leverage to reduce the sanctions connected to their financial and technological transactions. By summer 2022, Russia exported one third of previous amounts pushing the EU gas prices to a more than tenfold increase (McWilliams et al., 2022).

In efforts to replace the dependence on Russian gas, Europe had to seek import from alternative sources, leading to elevated prices of liquefied natural gas (LNG) supplies from Australia, the US and the Middle East (IEA, 2022h). Exporters of natural gas rushed to expand production and export capacities to meet increasing demand. However, the implementation of these projects takes years to realize, leaving a time lag together with a gap between increasing demand and available supply of natural gas. The Chinese economy has recently been in a slowdown, resulting in a greater availability of LNG in Europe. While this augmented supply has provided some relief, partly alleviating the crisis, it has not been enough to fully meet demand (McWilliams et al., 2022). Moreover, global oil prices surged as many countries abstained from purchasing Russian supplies, with some shipping companies even refusing to carry Russian oil due to concerns over the imposed sanctions. As the investments in oil and gas have been low the past few years, many oil producers were unable to boost the supply to meet the new demand, leaving the market vulnerable to potential turbulence. However, the prices reached their peaks and has steadily been declining since late 2020 (IEA, 2022h). This downward trend which has persisted throughout spring 2023, could provide some breathing room for the energy market, and create an opportunity for renewable energy sources to gain further traction.

Due to unfortunate weather and maintenance issues during the year 2022, there has been reduced capacity to generate power, and the access to energy has been further limited. The dry weather experienced in the northern hemisphere during 2022 caused draught and severely impacted hydropower generation in numerous major river systems in China, Europe and the US. These river systems are vital to meet energy demand combined with environmental targets, as they collectively are responsible for almost half of low-carbon energy supply globally (EIU, 2022). During 2023, however, hydropower production capacity is predicted to return to higher levels as the drought in 2022 was expressed by Andrea Toreti, member of the European Commission Joint Research Centre, to be the worst drought event to occur the past 500 years (Blade, 2022; EIU, 2022).

Extreme weather events are expected to increase in the coming years. The Economist Intelligence Unit (EIU), a research and analysis department of the Economist Group, predicts a rise in extreme weather events, that will lead to future short-term power crisis . These crises are likely to compel countries to fall back on fossil fuels, particularly the countries who rely heavily on hydropower such as China, where it accounts for more than 10% of total generation, and Brazil where hydro makes up 60% of total electricity generation (EIU, 2022). The fallback on fossil fuel options might further delay the transition to renewable energies, and, equally important for many nations, will result in higher carbon emissions. Many countries worldwide have announced decarbonization strategies and net-zero targets. An uptake in the burning of fossil fuels would undermine their efforts to achieve these climate related goals. It is crucial that renewable energy systems are designed to be resilient and

diverse to effectively address the concerns associated with extreme weather events. Countries' commitment to the energy transition is evident in their implemented and announced policies, which prioritize energy security concerns. These policies indicate an acceleration in the deployment of renewables and emphasize the adoption of a diverse portfolio of clean energy sources. The collective effort demonstrates dedicated strategies towards addressing energy-related challenges, fostering a future characterized by both sustainability and secure supply of energy.

The weather and dry dams pose challenges for hydropower generation, but the draught also impact coal-fired power which require water to transport coal, and thermal and nuclear plants that rely on water for steam generation and cooling among other purposes. The French nuclear power plants needed to shut down for maintenance purposes due to corrosion, coinciding with the closure of German nuclear, further intensifying energy supply problems in Europe (Jones, 2023; Toreti et al., 2022). The shutdown of these nuclear plants has particularly increased the demand for natural gas in Europe, partly offset by recent investments in increased production of American gas. Additionally, the slowing of the Chinese economy in 2022 has led to an increase in the available supply of natural gas for European importers (McWilliams et al., 2022). French and German nuclear plants are expected to resume operations in 2023, together with increased production from wind and sun energy sources. Therefore, it is likely that the demand for imported energy, especially gas, has decreased in Europe during spring 2023, a trend which is anticipated to continue into the following months (Jones, 2023).

In growing need for additional energy, almost all energy sources are affected, and short-term solutions are being exhausted. One of the temporary measures that has been taken to meet the demand, has been increased utilization of coal. Available supply of coal has been limited, leading to a threefold price increase in the coal marked. The supply disruptions following the war created a gap equal to 7% of Europe's total demand for electricity, with roughly one sixth of this gap filled by increased fossil fuel production, primarily coal. Fortunately, solar and wind had the capacity to partially bridge the deficit, in conjunction with a falling demand. This effectively reduced the extent of coal utilized to generate energy, mitigating the polluting emissions it would have produced (Jones, 2023). Coal is widely recognized as an unsustainable energy alternative to meet European energy demand, primarily due to the high emissions and environmental concerns, as well as the limited resource capacity in the foreseeable future. According to the IEA, the increase in coal from the energy crisis is temporary and does not push for investments in new coal-fired assets (IEA, 2022e). Furthermore, the utilization of coal is currently declining as the EU takes active measures to scale down the coal market, resulting in actual reductions in coal consumption. There are expectations of new measures on the horizon, aimed at further reducing coal consumption and supporting greater integration of renewable energies in the energy mix (McWilliams et al., 2022). Contrary to the increase in burning of coal, the new international

energy trade patterns spurred by the rupture of Russian energy supplies, with the orientation towards renewable sources, is a trend that is predicted by to be persistent and on a permanent basis (IEA, 2022e).

Transitioning to renewable energy sources

Renewable energy

The choice of energy source has implications for greenhouse gas emissions and the global climate as there is a consensus in the scientific field about the impact humans have on global warming. Energy production, all sources included, account for around 75% of greenhouse gas emissions globally (Ritchie et al., 2022). Renewable energy sources are recognized as a viable alternative to fossil fuels for their environmentally friendly nature, and are perceived as clean energy sources, as they generate energy without polluting and causing environmental damage, in contrast with the burning of fossil fuels.

Renewable energy derives from sources such as biomass, the sun in the form of solar radiation, wind, water as in hydropower and tides of the ocean, and geothermal resources from underground heat generated far beneath the surface of the earth. Although the definition of this term from 2014 can seem old in the rapidly evolving field, Ellabban and colleagues provided a concise and well-articulated definition of the term: “Renewable energies are energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photo-chemical, and photo-electric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy).”(Ellabban et al., 2014, p. 749). It is important to note that their definition excludes energy resources deriving from fossil fuels, including energy from nuclear power plants, as well as waste products generated by fossil fuels and inorganic waste materials.

Renewable energy comes from sources that are inexhaustible, unlike fossil fuels that originate from sources that are finite, even if they may appear abundant. In the case of fossil fuels, extraction today typically results in reduced availability of the resources in the future, leading to eventual depletion. To support access and use of fossil fuels, there needs to be a constant cycle of exploration and extraction, which is costly to operate. Renewable energy sources such as the sun and the wind, on the other hand, are not subject to the same limitations. They may be considered limited in certain aspects, as they are influenced by intermittent and temporary factors, like the absence of wind or sunlight. These sources replenish themselves naturally and the extraction or generation of energy using renewables does not compromise future access. This fundamental difference between fossil fuels and renewable energy sources underscores the long-term viability and sustainability of utilizing renewables compared to the finite nature of fossil fuels.

The perpetual access to renewable energy renders these sources reliable, and at times more economically efficient alternatives to fossil fuels. However, it is the environmental advantages of clean energy that make renewable energy sources the preferred alternative to fossil fuels in efforts to mitigate the effects of climate change. This has long been the biggest driver for transitioning to renewable energy sources at the global level. Other motivations for transitioning to renewables and diversifying the future energy mix include increased energy access and security, as well as lowering the vulnerability towards fossil fuel provisions and price fluctuations.

Sun and wind are the renewable energy sources most frequently referred to in reports and publications on the issue. It is worth noting that hydropower is sometimes excluded from the definition of renewable energies, due to the environmental impacts the installations of the power plants have for the local rivers and landscapes. Despite the environmental concerns, hydropower is one of the most established and utilized energy sources. When considering the entire life cycle of a hydropower plant, it has one of the lowest greenhouse gas emissions, and possesses high efficiency rates compared to other alternatives (Dones et al., 2004; Maradin, 2021).

Literature on the field of energy often discuss “alternative sources of energy” rather than solely renewable energy sources, as alternatives to fossil fuels. The alternative sources of energy include nuclear power generation which have not been considered as a part of renewable energy sources in this text, although in a wider context it is considered a low carbon energy resource. Some definitions of renewable energy include nuclear, even though uranium deposits are non-renewable. While nuclear electricity generation does not emit greenhouse gas emissions directly, there are significant emissions associated with construction of facilities and the procurement of essential minerals. Additionally, the storage of radioactive nuclear waste is a disputed issue, with its implications for human and environmental health (Maradin, 2021). Furthermore, findings from a research published in 2020 indicate that renewables and nuclear tend to crowd out one another (Sovacool et al., 2020).

Share of renewable energies in the energy mix

Today the renewable energy sources serve as supplements to the conventional forms of energy globally, although, in some countries they account for a significant share of national energy supply. Renewable electricity reached new heights in 2021, which broke previous records for total production capacity from renewable sources (IEA, 2021b, 2022a). In 2019, renewable energy technologies generated roughly 11% of the global primary energy (Ritchie et al., 2022). The global average of energy generated from renewable sources increased by 7% from 2019 to 2021 (BP, 2022; Our World in Data, 2022). This number encompasses the energy consumed for electricity, transport and heating. Renewable capacity was expected to

grow by 8% in 2022 (IEA, 2022a). However, unless swift implementation of new policies take place, the growth rate is expected to stabilize in 2023, primary as the expansion of solar photovoltaic (PV) is offset by a 40% decline in hydropower capacity and a plateau of the additions in wind power installations (IEA, 2022a). The share of renewable energies in the overall energy mix indicate that the world already was on a path towards an increase in renewable energy technologies before the energy crisis. The announced and implemented policies during 2022, including significant measures such as American Inflation Reduction Act and the European REPowerEU, reflect a growing commitment to integrate a higher level of renewable energies in the global energy mix. The aim of these policies is both to reduce reliance on fossil fuel imports and mitigate environmental impacts of pollution. However, the current percentage of renewables in the energy mix also implies that there still is a considerable way to go to in achieving a comprehensive energy transition.

A complete reliance on renewables might not be a desired objective in the near future. The transition process takes time, and building a resilient system based on renewable energies is not currently feasible due to various factors. The existing energy systems and infrastructures have been predominantly designed for fossil fuels and associated technologies, presenting challenges of integrating and accommodating for large-scale deployment of renewable energies in the immediate future. Additionally, there are limitations in energy storage solutions to offset the intermittency of renewables that needs to be solved, and technological advancements that take time to develop and execute in order to facilitate for an energy system predominantly based on renewable energy sources. These challenges underscore the limitations that would arise if the world was purely reliant on renewable energy capacity. As the world progresses towards greater reliance on renewable energy sources, both clean energy and fossil fuel systems need to co-exist and operate effectively to ensure provision of energy services needed in society. Premature retirement from the fossil fuel infrastructure may cause detrimental consequences for energy security (IEA, 2022e)

In the transitional process, it is crucial to emphasize the importance of incorporating a significant share of renewable energy in the global energy consumption during the transition period. Despite the existing challenges, energy generated from renewable sources offer benefits in mitigating the risks associated with global warming and reduction of greenhouse gas emissions. Investments towards renewable energy technologies are essential to overcome these challenges and develop viable solutions. Therefore, a balanced approach is preferred, which entails a combination of expanding renewable energy capacity, advancing technological innovation, and reducing reliance on fossil fuels. Besides the environmental concerns in this process, there are also economic factors and energy security concerns, that were elevated after the invasion of Ukraine. These factors highlight the importance of striking a balance between renewable energy deployment and fossil fuel reliance.

There are disparities among countries when it comes to the integration of renewable energy sources in their total energy mix. The average proportion of electricity deriving from renewable sources was at 28% globally in 2021, according to the IEA. It is crucial to emphasize that this percentage reflects the proportion of renewables in the electricity mix. The share of renewables in the energy mix is expected to be significantly lower considering the composition of the overall energy mix, including energy consumed in association with transport and heating. Some countries have deployed a greater capacity for renewable energies than the average, as well as implementation of other green technologies and green initiatives. On the other hand, some countries have a lower percentage than average. Oil-extracting countries and those with low levels of economic development have demonstrated limited adoption of alternative and more sustainable energy sources. Kuwait, Algeria and Turkmenistan are among the countries that fall into both these categories (United Nations, 2022; World Bank, 2019).

Overall, there is a general east-west divide between countries, where global Eastern and developing economies have a smaller share of energy from low-carbon sources than Western countries that typically are more developed. The developed countries France, Iceland, Norway, Paraguay, Sweden and few others in Middle and Southern Africa get more than 90% of their electricity from nuclear and renewable sources . Significantly increasing the global average of renewable energy in the energy mix. However, the above-mentioned percentage represent the share of renewables in electricity rather than total energy consumed. Taking into account the energy consumption for transport and heating purposes, the overall share of renewables is likely to be lower. When considering the percentage of energy sources from low-carbon sources, France falls to 49%, whereas the numbers are a bit higher for Sweden and Norway with 69% and 66% respectively (Ritchie et al., 2022). About 85% of energy consumption in Iceland in the year 2020 came from domestically produced renewable energy sources according to the Icelandic National Energy Authority (Ministry of the Environment, Energy and Climate, 2022), which is one of the highest percentage of renewables for one nation. The Icelandic definition of renewables include hydropower in contrast to other definitions where it might be considered low carbon but not renewable. Iceland is one of the countries that have come the furthest in transitioning to renewable energy and the government has set goals to continue to improve and cut emissions as part of the Paris Agreement and in cooperation with Norway and EU. These agreements aim to reduce emissions by 40% by 2030 compared to 1990. Iceland has put forth a national goal to reduce emissions by 55% in the same timeframe (Ministry of the Environment, Energy and Climate, 2022).

Renewables have generated record high percentages of total energy production in many countries this past year. Overall hydropower generation has been relatively stable and descending from about 46% in the early 2000s, dropping from 37,5% in 2021 to 32% in 2022, mostly due to weather conditions affecting water accumulation in the dams (Jones, 2023).

Wind and solar account for about a fifth or 22% of EU electricity in 2022, remaining above coal generation at 16%, and for the first time overtaking fossil gas at 20% (Jones, 2023). Note that 20% is the percentage of fossil gas in the energy mix, and not all fossil fuels, which would amount to higher numbers. It is the first time renewable energies generate more power than gas in the EU. The remaining 10% of the EU energy mix comes from other fossil fuels, bioenergy and other less common renewable sources (Jones, 2023).

The IEA anticipates the renewable capacity expansion in the next five years to be much more rapid than expected a little over a year ago, leading to a forecast of an average of 38% of energy coming from renewable sources by 2027 (IEA, 2022f). The acceleration is predicted to be primarily driven by the US, India, China and the EU, all of which have existing policies in place and are currently implementing market and regulatory reforms, while also introducing new measures at a faster pace than anticipated in response to the energy crisis. Examples of the implemented policies are the US Inflation Reduction Act, China's 14th Five-Year-Plan together with a market reform, and the REPowerEU plan published in May 2022 after the invasion of Ukraine (IEA, 2022f). The changes in the forecast of the IEA from 2021 to 2022, is primarily influenced by the implementation of these initiatives, which has led to an anticipation of a faster transition to renewable energies compared to what was expected prior to the energy crisis.

The tone of accelerated clean energy development in advanced economies this decade is being set by new policy packages, government plans, and ambitious targets. The US Inflation Reduction Act plays a major role in shaping this trajectory, increasing the funding and deployment of renewable energies in the United States. Europe has experienced an accelerated deployment of renewable energy sources and developments made in energy efficiency in the EU are projected to drive down regional demand for fossil fuels considerably. The increasing deployment of clean energy is driven by urgency to find trade partners and sources of economic and industrial advantage outside of Russia and their gas supplies (IEA, 2022e). Major European policies such as the REPowerEU, "Fit for 55" package, the Energy Performance of Buildings Directive, and revision of the European Green Deal demonstrate a strong commitment to enhancing the proportion cleaner energy sources and drive progress towards climate and environmental targets. Korea aims to increase the proportion of renewable energy and nuclear sources in its energy mix. India, although classified as a developing economy, continues to make progress in achieving its target of 500 gigawatts (GW) of domestic renewable capacity by 2030, with renewables accounting for two-thirds of the country's rapidly growing electricity demand (IEA, 2022e; United Nations, 2022). Furthermore, the Climate Change Bill of 2022 in Australia contribute to support the transition to cleaner energy and reduction of greenhouse gas emissions. The Climate Change Bill enshrines to law the targets of a 43% cut in emissions below 2005 levels by the year 2030, and the aim of achieving net zero emissions by 2050. While the bill may not specifically focus on support for renewable energy sources, it sets the stage for comprehensive action

that drives the necessary energy transition, most likely including renewable energy sources (IEA, 2022e).

Transitioning through energy sources

Historically speaking, transitioning from one energy source to another has been incredibly slow processes, driven by practicality or technological advancements. There have been instances which demonstrate the feasibility of moving from one dominant source of energy to another. The previous transitions highlight the possibility of realization of a new transition towards a higher dependence on renewable energies. Past transitions have been what can be called “emergent”, meaning they have emerged as a result of entrepreneurial curiosity and utilization of new technologies. The transition towards renewable energies, on the other hand, will most likely be a transition pushed through by coordinated efforts.

Within the field of political science, scholars have long recognized the significant impact of shocks and crisis on the political processes and their outcomes. One prominent theory that offer insights into the timing and causes of policy changes is the “multiple streams” theory. According to this theory, policy change occurs when there is a convergence on the perceptions regarding problems, proposed solutions, and political considerations, that align with the legislative measures (Kingdon, 1985). The energy crisis has emerged at a time when many countries were already on the path towards cleaner energy technologies, and the EU has seized the opportunity to expedite the transition to renewable energies.

Overall, there has been a broad consensus on the recognition of problems at hand, namely the lack of secure energy supply due to high dependence on imports from Russia. There has been a notable level of convergence regarding the solutions to address the energy crisis, as these have encompassed a range of approaches. These have varied from being acceptable in certain countries or political parties, such as utilization of nuclear power plants or regress to coal use. The solutions have also included strategies like prioritizing increased import from nations known to be reliable as energy suppliers, or the promotion of accelerated deployment of renewable energy technologies. In line with the aforementioned theories, exogenous shocks like wars and even more important for this thesis, the energy crisis, as well as changes in societal preferences, have potential to disrupt the context in which the transition unfolds (Victor et al., 2019).

A central challenge in transitions is how new technologies and innovations take hold in the existing system. Despite the potential of radical innovations, many of them fail to get a footing and establish itself in the market. This is particularly relevant for niche innovations, including several of the renewable energy technologies, which often can be more expensive and face issues with social acceptance. These challenges can be hindrances for a fast and efficient broad system transition, contributing to the protracted timeline, often decades, it

takes for these technologies to fully establish in society (Victor et al., 2019). The energy crisis, however, provide a shift in the landscape, facilitating for uptake of innovative renewable energy technologies within the existing systems.

The urgency of the crisis has changed priorities and incentivized governments and private stakeholders to seek out these alternative energy sources and reduce their reliance on fossil fuels. The potential for an acceleration of these technologies during the energy crisis is rooted in the need for new, viable solutions to address the challenges posed by the crisis. This altered context offer a greater chance for these technologies to gain momentum and overcome some of the barriers previously faced, aligning with the multi-level perspective and the increased potential for change in a shifting socio-economic landscape (Geels et al., 2017). Although, when policymakers act within a context of urgency, they are more inclined to utilize what they have at hand, including well-known policies, leading to an urgency-driven logic that prioritize immediate needs and short-term thinking over more nuanced strategies, potentially neglecting long-term planning, and limiting the time for inclusive and deliberate decision making (Patterson et al., 2021).

The drawbacks on short-sighted politics in relation to clean transitions and the need to effectively manage the process for long-term progress, have been well-documented (Hughes, 2018). Additionally, previous efforts to pursuit urgent energy security goals have demoted other goals, particularly related to climate and decarbonisation (von Homeyer et al., 2021). This security approach has the possibility of complicating the transition process, especially regarding redistribution of funds and policymaking. However, this does not seem to be the trend among major global policymakers, as there have been fundamental changes to current policies and launches of packages such as the US Inflation Reduction Act and REPowerEU. These policy packages work towards improving not only economic stability and energy security, but also expedite the adaptation of renewable energy technologies and energy efficiency measures (IEA, 2022f).

Incentives to transition

The increasing need for sustainable and resilient energy systems drive the investment and policy support for innovative technologies, which can turn out to play a pivotal role in mitigating the impacts of the energy crisis and pave the way for a more sustainable and secure energy future. Regarding this, Steffen and Patt argue that the invasion of Ukraine has served as a historical turning point for energy policy within Europe, heightening the need for diversification of energy sources, and reevaluating the previous energy systems and strategies, opening a “window of opportunity” for accelerating the transition to net-zero energy systems (Steffen & Patt, 2022).

Until the energy price surge in 2022, the incentives for an energy transition towards greener sources have been limited. The initial cost of installing renewable energy projects has typically been substantially high, which made them less competitive in price compared with the well-established fossil fuel plants. Moreover, the goal of seeking sustainability or reducing environmental damage has been perceived more of a collective good rather than purely benefiting individuals and companies. This perception of sustainability and environmental good entails prisoner's dilemmas and free rider problems (Geels, 2011), which discourage active participation from private actors. These factors collectively contribute to a slower than optimal progress of the transition to renewable energies before the energy crisis, as the issue has been primarily viewed as a communal objective, and both businesses and individuals have had limited economic incentives and motivations beyond environmental concerns.

The aspect of collective benefits in sustainability has been used to emphasize the importance of public authorities; the governments and international bodies' role to address the need for a change of energy sources. Policymakers are in a position to support innovation, coordinate actors, and shape strategies for investments (Victor et al., 2019). Their contribution to change the economic frames in choice of energy sources and support low carbon technologies has been viewed as crucial in much of the existing literature (Geels, 2011). Although past energy transitions have been opportunity-driven, public policy has been involved in most historical transitions, therefore it is adjacent to think that policymakers will play the important role as drivers for the coming energy transition.

Governments and industries have become more organized over time. For the governments and policymakers this means a better chance at cooperation at the international level, and stronger force to push policies through if the commitments are there. Prominent scientists known in the field of societal and energy transitions such as Frank Geels, call for a stronger degree of international cooperation, with a focus on the process of transitioning rather than the end-goal (Victor et al., 2019). On the other hand, modern industries have also been increasingly organized and entrenched, meaning they have a strong ability, power and intention to resist change, as many of the biggest industries in the world are carbon-intensive and fossil fuel driven (Victor et al., 2019). However, as incentives to choose cleaner energy sources have changed the past year with the price of renewable energy being made cost-competitive after the invasion of Ukraine, different actors seem more motivated to invest in greener energy. Most notably, governments and private businesses are looking to invest in energy from trustworthy energy sources outside of Russia, seeking to secure local or regional supply of energy. This can be viewed as efforts that increase energy security with the positive effects of taking a step closer towards renewable energy.

Economic factors

The energy crisis has prompted a notable escalation of investments towards renewable energies. Marked by the unprecedented challenges in energy supply and distribution, along with lack of affordability, the crisis has become a driving force behind substantial changes in the global energy landscape. Increased investments in renewable energies unlock the potential for greater energy diversification, leading to enhanced energy security and improved access. Moreover, investments in renewables yield notable socio-economic benefits, including enhancement of human welfare, the creation of employment opportunities and overall economic growth. A transition towards renewable energy sources in the energy system supports a workforce within manufacturing, installation, operation and maintenance of new infrastructure. The growth of this industry fosters further investments and innovation, along with promoting local economic development. An energy sector based on renewables will also be less exposed to price volatility compared with fossil fuels, thus providing a greater stability for both energy and economic systems, which can have a positive impact on households and businesses.

Energy prices started to rise in 2021, as global energy demand increased after the pandemic and as a result of low investment in the energy sector the previous years. It was not until the invasion of Ukraine spring 2022 that the prices soared to historically high levels for all energy sources. The prices increase was exceptionally high for natural gas, given the disturbances in supply of this particular commodity to Europe from Russia (Ari et al., 2022). The country generally has a huge footprint in fossil fuels, both as it exports a lot of gas, and because it utilizes large quantities of coal, crude oil and natural gas. Russian fossil fuel export accounting for around 5% of coal, 10% of oil and 20% of gas at the global level (Ari et al., 2022).

Russia was deeply integrated into European and UK energy markets, supplying the region with coal, crude oil and natural gas with 45, 25 and 35%, respectively. This is an issue in the current situation, as many European countries lack pipeline connections to other sources of liquefied natural gas (LNG) that would allow them to replace supplies from Russia during this period. The limited access through pipe infrastructure contributed to the cost increase, leading the prices following the invasion to double for crude oil, triple for coal and an increase more than five-fold for natural gas prices compared to the prices of early 2021 (Ari et al., 2022; Butler, 2022). The IMF expects half the increase in coal and crude oil to persist until 2026, and about a quarter of the price of natural gas to last throughout 2026. At the same time, EU cap-and-trade carbon allowances more than doubled due to the adaptation of enthusiastic goals in emission reductions by the EU (Ari et al., 2022).

Although the EU Emission Trading System (ETS) more than doubled in cost, this only counts for about 10% of the price increases. In a decomposition exercise provided by Bloomberg Finance L.P. and IMF staff in an IMF report on “Surging Energy Prices in Europe in the

Aftermath of the War" (2022), the increased natural gas prices is calculated to account for the remaining share, around 90%, of the overall rise in wholesale electricity cost since the first quarter of 2021. This pricing system employed by the EU is based on an overall price determined by the highest price bids among the accepted offers to meet consumer demand. When there is high demand for energy, the highest bid often comes from a fossil fuel plant, which most typically is a natural gas plant (Ari et al., 2022).

The surge in fossil fuel prices has created fortune for some energy producers, most notably the ones based on renewable sources, and losses for others. Due to the structure of the European energy market, domestic energy producers within the technologies with mostly unchanged costs of operating and marginal costs. These producers include the industries for renewables and nuclear, which have the same expenses related to generation of electricity as the marginal unit price surges, typically set by fossil fuel plants. The European system for energy prices is based on the "marginalist" system, where all producers are paid the same price regardless of the production expenses. Therefore, producers of renewable and nuclear electricity have considerable benefits when the price for fossil fuel increases and these powerplants set the price for energy in the region. While the manufacturing and installation for renewable energy technologies can be costly, their operational expenses are primarily limited to maintenance. The prosperity of renewable energy sources lies in the abundant generation of energy, free from extraction costs financially burdening the fossil fuel industry. Some clients have long-term contracts with producers at a pre-established price, meaning that when the spot market prices increase, producers sell for the agreed price instead and would not benefit as much from higher regional energy prices.

The price for wholesale electricity, particularly, has varied between countries together with their dependence on different energy sources. European countries with limited electricity and energy connections have had constraints in the extent of access to energy suppliers, primarily due to high reliance on gas. Because of the EU price setting system, the gas price has often been the marginal price setter. These countries have had issues importing from other areas and producers with lower prices, leading to more prominent increases in price. Price increases have been found to be lower in countries with less reliance on fossil fuels and more diverse energy mix. In this context, renewable energy becomes crucial to mitigate volatile and high energy prices. The Nordic countries are examples of this, where most electricity generation comes from renewables, including hydropower, resulting in lower energy prices compared with many other European nations (Ari et al., 2022).

A transition to green energy sources would significantly reduce electricity prices. Cevik and Ninomiya (2022) argue that a higher percentage of renewable energy in the energy mix would lower wholesale electricity prices and impact overall energy prices. An increase of renewable energy percentage by 1 point lowers the wholesale electricity price by around 0,6% on average, in the study executed on a panel of 24 European countries between 2014

and 2021. According to their text for the IMF on energy transition and electricity prices in Europe, Cevik and Ninomiya found that electricity prices could be reduced by almost 20% if power from solar and wind amounted to 50% of the energy consumed. This statement is based on numbers from the period 2014-2021, in which wholesale electricity prices was assumed to be reduced by 8.8% if the share of the renewables wind and solar had been double the actual average of 14% (Cevik & Ninomiya, 2022).

Although renewable energy would lower the price of energy, Cevik and Ninomiya advice policymakers to be cautious of creating a too heavy reliance on the renewables to meet energy demand. Because of the fluctuating nature of renewable energy sources like wind and sun, energy price volatility could be increased when production is low, thus leading to supply-demand imbalances, increased instability and higher price volatility and overall rises in wholesale energy price. A solution to this, however, could be a closer integration and modernization of electricity grids in Europe. This can be coupled with higher investments in technologies that dampen the effects of volatility, like energy storage, and technological solutions that reduce congestion on transmission lines (Cevik & Ninomiya, 2022).

The recent political developments in North America, Europe and many parts of Asia indicate a growing commitment to addressing these challenges (IEA, 2022e). It is evident that the focus on finding solutions and taking action to achieve the energy transition is becoming increasingly important for nations, exemplified by initiatives like the REPowerEU and the Inflation Reduction Act. These policies not only provide funding for renewable energy technologies, but also prioritizes investment in storage and grid solutions that facilitate the integration of clean energy sources. This commitment to address the challenges associated with integration of renewables, demonstrates a comprehensive forward-thinking approach among major international decision-makers, highlighting their dedication to achieve a more sustainable energy future.

The price of renewable energy

Renewable energy is a big step towards the green energy transition. One way of looking at high energy cost related to renewables is to look at the energy commodity prices. The energy crisis has pushed all kinds of commodity prices for energy sources to historical peaks worldwide. This part of the text will look at the costs for commodities related to production of wind turbines and solar PV modules to better understand the overall costs related to renewable energy source manufacture and essential resources, installation and freight.

For more than a decade, the costs of solar and wind power generation, together with necessary equipment, have been on a reduction trend, which changed two years ago. The increase of these prices in 2021 may cause delay for investments and completion of renewable energy projects. The financial feasibility of the projects face challenges with high

costs, as high commodity prices impact the implementation and progress of the solutions. The investors might become hesitant due to the concerns surrounding returns and progress, making more careful evaluations and prioritization of investments. The state of economic uncertainties calls for careful strategic planning to ensure continued momentum and realization of planned renewable energy projects.

The prices for industrial resources and freight of the essential materials needed for manufacturing renewable energy plants have been on an increasing trajectory since the start of 2021, impacting the price of solar and wind installations (IEA, 2021b). The production of renewable energy plants relies heavily on materials such as steel, copper, aluminum and polysilicon, which play an important role in the manufacture of the plants themselves and associated parts. The price of essential material for renewable energy projects has increased overall, and although some prices for commodities have fallen, the cost are pushed up by high interest rates, a particular issue for developers of solar and wind farms, as these project even prior to the energy crisis, require a higher initial capital investment than fossil fuel power plants (The Economist, 2023).

The cost associated with transport of the essential materials has had an impact on the overall energy price. The cost of the transport, also called freight, has been gradually increasing for two decades, albeit with some fluctuation, but has seen a significant increase the past two years. The upward trend in freight prices highlight the challenges related to transporting of the essential materials needed to expand renewable energy capacity in times of high prices. Freight prices almost six folded, significantly adding to the total cost of solar and wind as the supply chain is geographically dispersed. Manufacturers have been trying to mitigate freight costs by buying materials from suppliers closer in proximity and have been using hedging clauses to pass rising commodity prices on to buyers (IEA, 2021b).

During 2020 and 2021 the prices for steel, copper, aluminum and polysilicon soared to new heights. The IEA estimates that these resources which they call “key commodities” together with freight constitute 15% of total investment costs for solar PV and onshore wind (IEA, 2021b). For solar, the biggest costs are related to manufacture and shipment, which is affected by the price of steel, aluminum and polysilicon. For electrical installation, copper is especially important. In wind installations, large quantities of steel are used in constructing the nacelle, tower and other mechanical equipment. These materials are bulky and oftentimes heavy, which is why up to 6% of costs for onshore wind are associated with transport (IEA, 2021b). Moreover, there have been raised concerns over the origin of the materials and equipment needed for renewable energy technologies, leading to elevated price increases in the EU, the United States and India (IEA, 2021b).

In late 2021, the price of steel had doubled compared to early 2020 and returned to a more regular price during late 2022 and early 2023, averaging around 25% higher than the price in

spring 2020 (IEA, 2021b; Trading Economics, 2023). This is closer to what has been the average price when looking at the past 14 years. Copper increased by 60% from early 2020 to late 2021, aluminum increased by 80% and solar PV graded polysilicon more than quadrupled (IEA, 2021b). Resulting in an increase in the cost of solar and wind, in a range of 10-25% worldwide depending on region and country. China is an exception to this, where demand for wind turbines have been declining because of competition among suppliers. The competition can be attributed to high production capacity after high deployment in 2020, together with a planned phase out of subsidies (IEA, 2021b).

Despite the rising trend in prices, the cost associated with renewable energy generation has remained relatively lower compared to the elevation in price of fossil fuels, especially natural gas and coal. This fosters a favorable environment for the deployment of renewable energies, as well as increasing the competitiveness of green energy solutions in the market. Consequently, there has been a high demand for solar PV and wind in most of Europe (IEA, 2021b). However, if the prices of steel, copper, aluminum and polysilicon persist at their current rate, the investment expenses for renewable projects are likely to remain high and slow the pace of the energy transition. Nonetheless, the supply issues associated with the fossil fuel industry are likely to push for continued investments made in alternative, greener energy initiatives.

Manufacturers reported fewer orders in the first quarter of 2021, because the commodity prices increased the price of the finished products. Many American and European wind turbine manufacturers reported increasing prices with as much as 10 to 25% (IEA, 2021b). During the year, however, buyers accepted the new market conditions with a sense of perceiving high prices as the new normal, leading to a growth in demand during summer of 2021 (IEA, 2021b). This indicates that increases in prices of renewable commodities can be adapted to and will not necessarily lead to declines in sales in the long-term. Underlining that the greater significance on a larger scale is attributed to the overall profitability of the renewable market, rather than the high initial investments. However, the fact that consumers are willing to accept and adjust to high prices can also be used as an argument in favor of fossil fuels. For this reason, the economic profitability of renewable energy production will be even more crucial for scale and timeline of the transition.

When looking at previous trends for cost reductions, higher commodity price could lead to increased investment costs by USD 70 billion for solar PV and around half, around USD 35 billion for onshore wind in the period of 2021-2026 (IEA, 2021b). Increases at this scale are likely to affect the pace of deployment as well as execution and completion of projects. The IEA expects the trade measures and supply constraints related to solar PV and wind turbines to have a short- and medium-term impact on markets, with high effect on cost, investments and project profitability, especially for auctions and developers that was settled prior to the price increases (IEA, 2021b). However, the worldwide inflation related to commodity prices

together with concerns over banks raising interest rates, have caused uncertainty which present long-term risks for price fluctuations, which impact investments in renewable energies, lead to higher costs for governments and developers, and can slow the pace of transitioning to clean energy sources.

It is yet too early to assess medium- and long-term implications for the deployment of solar PV and wind, but so far, the higher commodity prices have had a limited impact on demand for capacity. Renewable energy sources seem cost competitive as corporate purchase is on track to set a record. There have been no large changes in policies or cancellation of government-led auctions, which are crucial for keeping deployment stable. If the cost of commodities and freight for the renewable energies are stable and continue their reduction trend, the long-term implication for solar PV and wind demand are likely to be minimal. However, there is a risk that the prices will remain high over a period of time, and further increase interest rates and inflation, slowing the expansion of solar and wind capacity, and rising the cost of the renewable energy transition (IEA, 2021b).

Investments

The energy crisis presents challenges to the global energy sector, which require strategic investments to ensure a sustainable energy future that promotes energy security, including affordable access to energy. This part of the thesis examines key economic factors related to the energy crisis and the transitioning to renewable energy sources. More specifically, it will look at the investment trends within the energy sector. Exploring the role of investments in shaping the energy transition and the stimulating the shift towards renewable energy solutions.

Investments in energy transition technologies are at record high numbers (IRENA & CPI, 2023). In 2022, there was an amount of USD 1.3 million invested for the purpose of development and deployment of this kind of technology, which is 19% higher than the investments made in 2021, and 70% higher than pre-pandemic investments made in 2019 (IRENA & CPI, 2023). The energy technologies include not only renewable energy, but also energy storage, energy efficiency, electrified transport and heating, hydrogen, and carbon capture and storage (CCS). The technologies are perceived as crucial in transitioning to the alternative energy sources, in addition to the objective of reliance on renewable energies. The increasing investments in the energy technologies indicate that there is a growing recognition for the environmental and energy security risks associated with reliance on fossil fuels, and shows that investment in renewable energies, and the energy transition in general, is progressing over time, while also indicating that there has been an acceleration after the crisis. A relevant question arises as to whether these investments are sufficient to accelerate the pace of the energy transition, or merely adequate to facilitate a gradual shift over time.

In a report by International Renewable Energy Agency (IRENA) and Climate Policy Initiative (CPI) (2023), titled “Global landscape of renewable energy finance”, Francesco La Camera, Director-General of IRENA, states: “annual investments need to at least quadruple to remain on track to achieve the 1.5°C Scenario laid out in IRENA’s World energy transitions outlook 2022” (IRENA & CPI, 2023, p. 8), putting forward a target for investments in energy transition solutions in order to achieve the 1.5-degree goal. Investments in renewable energy, specifically, had record high numbers in 2022, at USD 0.5 trillion, a 16% increase from 2021 (IRENA & CPI, 2023). Which is progress in the right direction, but according to IRENA and CPI, the investments only represent one third of the annual investments towards renewables required between 2023 and 2030 to achieve IRENA’s 1.5-degree Scenario. Neither are the current levels of investment on track to achieve the goals connected to improved livelihoods and welfare included in the 2030 Agenda for Sustainable Development (IRENA & CPI, 2023). The 1.5-degree target and the 2030 Agenda are closely intertwined with the transition to renewable energy sources, as the implementation of these sources play a major role in limiting global warming to below 2 degrees Celsius above pre-industrial levels, as outlined in the Paris Agreement. The target highlighted the pressing need to expedite the transition towards renewable energies, already before the eruption of the war in Ukraine, which triggered the energy crisis and further amplified the imperative to move away from fossil fuels.

La Camera underlines the urgency and emphasizes the challenge of transitioning, as the energy crisis has created an uncertain macroeconomic landscape which have forced some countries to deploy alternatives to conventional energy sources (IRENA & CPI, 2023). While temporary measures may be required in response to the crisis, it is imperative that the justifications for deviating from climate goals will not be accepted in the medium or long term. The urgency of addressing the energy crisis, should not however overshadow the long-term commitment to climate targets and investments in renewable energy coinciding with enhancement of long-term bolstering of energy security. Furthermore, IRENA’s report on cost of renewable power generation in 2021, states: “The situation in 2022 provides a stark example of just how economic new renewable power generation has become and the benefits it has in insulating economies from volatile fossil fuel prices.”(IRENA, 2022). Further underlining that renewable power can liberate economies from the volatile prices associated with fossil fuel systems and the high reliance on imports. Renewable energies contribute to curb the energy costs and bolster market resilience, particularly in the context of the current energy crisis and with even greater significance if the energy crunch persists (IRENA, 2022).

Implementation of new policies in the major energy markets is expected to drive annual clean energy investment. According to IEA’s Stated Policies (STEPS) pathway, the implementation of policies is projected to help accelerate the investments with more than USD 2 trillion by 2030, representing an increase of more than 50% compared with present-

day investment levels (IEA, 2022e). This pathway assumes that announced policies, existing and those under development, will be implemented, like National Determined Contributions under the Paris Agreement and other stated policies (IEA, 2022g). Much of the expected elevation of investment can in large part be attributed to the US Inflation Reduction Act which is assumed to have a significant impact on the energy landscape going forward.

The annual solar and wind capacity in the United States is likely to grow by two-and-a-half-times compared to current levels. Furthermore, the recent adaptation of the Inflation Reduction Act and the Bipartisan Infrastructure Act in the US is expected to catalyze an accelerated funding and deployment of renewable energies and provide a substantial boost to the wide range of clean energy technologies (IEA, 2022e). The Inflation Reduction Act allocates USD 370 billion towards energy security and battling climate change, which has the potential to attract greater funding from private actors. The investments through the Inflation Reduction Act comes in addition to the USD 190 billion invested in clean energy and mass transit in the Infrastructure and Jobs Act passed in November 2021. The legislations amount to a total of nearly USD 560 billion in investments earmarked for clean energy. Together, these initiatives considerably improve the ability to deploy renewable energies in the US and majorly contribute to the mitigation of greenhouse gas emissions (IEA, 2022e).

Investments in renewable energies worldwide are mainly concentrated by large incumbent firms and dedicated to specific technologies. Investments outside the governmental subsidies and contracts are made among seven major incumbent firms that have established themselves, with aims to expand their market position. From 2017 to 2020, the average transaction size increased from USD 1.1 million to 1.7 million, then doubling in 2021 to 3.7 million (IRENA & CPI, 2023). Price increases such as these can be seen as an indicator of growth and as signs of a maturing industry, though, it also suggests that there are challenges for firms looking to make smaller investments. About 90% of renewable investments each year go to power generation purposes, much of which is dedicated to solar and wind technologies. 43% of the total investments went to solar PV, and offshore and onshore wind respectively attracted 13 and 35% of the total (IRENA, 2023; IRENA & CPI, 2023).

Following the emergence of the Covid-19 pandemic in 2020 and the subsequent global energy crisis, the fossil fuel industry also reaches records, reaching all-time highs as subsidies rise above USD 1 trillion in 2022 (IEA, 2023c). While the provided subsidies to the fossil fuel industry has partially protected consumers from the peak costs, according to an analysis conducted by the IEA, the increased subsidies runs counter with the Glasgow Climate Act, which calls for the phase-out of inefficient fossil fuel subsidies to support the most economically vulnerable (IEA, 2023c). However, rather than supporting this group, the subsidies effectively offset some of the cost associated with fossil fuel operations, upholding the cost-competitiveness of fossil fuels compared with low-carbon alternatives, impeding progress towards renewable energies (IEA, 2023c).

The financial incentives this industry receives are instrumental in maintaining their operation and production. The subsidies have doubled in 51 countries in 2021, with consumption subsidies expected to have risen further during 2022 due to pressures in price. Indicating a significant increase in governmental assistance towards this industry. Between 2013 and 2020, there was a total global expenditure of USD 2.9 trillion dollars towards fossil fuel subsidies, with the most subsidies provided in Europe, overtaking the Middle East and North Africa (MENA). Over an extended period, the MENA region has consistently provided the highest number of subsidies for fossil fuels, surpassing the other regions by a large margin. However, in 2020, MENA reduced its support for fossil fuels (Fossil Fuel Subsidy Tracker, 2022). On a per capita basis, subsidies in MENA amount to more than triple those in for Europe (IRENA & CPI, 2023).

The continued investments in fossil fuels and inadequate redirection of funds towards renewable energies poses a challenge for the transition to these cleaner energy sources. To achieve a transition to cleaner sources of energy, approximately USD 1 trillion per year needs to be redirected from fossil fuels to transitional technologies, where most of the investments go to renewable energy sources (IRENA & CPI, 2023). The lack of sufficient funding for renewables is estimated at a value of USD 570 billion every year until 2030, which is hindering progress of transitioning to renewable energy sources. In extension of this challenge, banks and investors have signed contracts and committed themselves to financing of fossil fuel projects above the limit of polluting emissions needed to be mitigated in order to achieve the 1.5-degree target. On average, multi-national banks have increased investments in fossil fuels by USD 750 billion dollars annually since the Paris Agreement in 2015 (IRENA & CPI, 2023), thus, perpetuating the trend of reliance on polluting energy sources.

On the other hand, there is a possibility that oil and gas companies themselves could play a leading role in the energy transition. While these companies have historically been associated with fossil fuel extraction, many of them are now recognizing the need to invest in more sustainable energy sources. This is not new in the industry as the first companies in the fossil fuel industry started to invest in renewable generation through solar and wind projects in the early 1980s (Asmelash & Gorini, 2021). Many of the companies have already rebranded themselves as being in the energy industry rather than solely in the oil and gas branch, distancing themselves from the fossil fuel regime (Lu et al., 2019). There are clear incentives for the oil and gas industry to invest in alternative sources beyond fossil fuels. Diversifying their investments allow them to tap into alternative markets, reduce their reliance on revenues from fossil fuels, and put them in a position to boost a low-carbon economy. Furthermore, investing in energy sources aligning with societal values and regulatory pressures, presents an opportunity for these companies to demonstrate their commitment to sustainability and mitigating climate change. Prioritization of sustainability

will positively impact their business image and performance, especially if consumer preference for clean energy sources remains high. It is important to note, however, that oil and gas companies have a history of denying anthropogenic climate change and engaging in "greenwashing", where they portray their industry and products as green, environmentally friendly, or invest in renewable energy projects with the underlying intention of promoting sales of their fossil fuel products (Megura & Gunderson, 2022; Si et al., 2023). Such actions can be perceived as deliberate efforts to obstruct climate action and delay the energy transition and is likely to negatively impact the public's perception of these companies and undermine trust in their environmental commitments.

Several major players within oil and gas, such as Petronas, Equinor, Shell and Total, have announced that they will have net-zero emissions by 2050. These companies have outlined comprehensive strategies to reach this targes, involving the implementation of carbon capture and storage technologies to mitigate emissions related to fossil fuel consumption to ensure continued production, while also making significant investments in renewable energies (Asmelash & Gorini, 2021). The most prominent investors in renewable energies among the oil companies, are the nationally owned companies. For instance, China National Offshore Oil Corporation revived their activities in offshore wind power generation in 2019, after a 5-year hiatus of their renewable energy unit, which includes activities within wind, solar and biomass projects. Similarly, Saudi Aramco have long been interested in renewable energy and has recently launched a USD 500 million fund to improve renewable technologies and energy efficiency (Martin, 2017).

Overall, the investments in clean energy by oil and gas companies are gradually increasing. This trend is primarily led by major European players in the field and a select few other companies. In 2022, clean energy investments represented approximately 5% of the total capital expenditure of oil and gas companies worldwide, a notable increase from just 1% in 2019 (IEA, 2022d). The elevated investments can signify a response to global trends regarding clean energy demand and environmental concern, combined with recognition of the need to transition to sustainable energy sources. Additionally, the windfall gains provided by the energy crisis for fossil fuel exporting nations present them with a rare chance to a much-needed transformation of their economies, and diversify their revenue streams, as well as the opportunity to allocate sufficient funds to expedite the energy transition (IEA, 2022d, 2022e).

When do we favor renewables?

The energy crisis changed how investments in greener technologies are perceived. Often, cost is a strong factor when choosing one type of technology over another. However, as the energy crisis has increased commodity prices, especially related to the cost of fossil fuels, greener technologies are positioned with the prospects of becoming the more profitable

option. The electrification of heat, specifically through the implementation of heat pumps, serves as a valuable example. In the EU, close to 60% of household heating is powered by fossil fuels, with two-thirds coming from natural gas (Calthrop, 2022). In order to enable the transition of European heating towards more sustainable alternatives, an obvious approach would involve adopting electric heat pumps operating on renewables or more environmentally friendly sources of energy.

The capital investment in a single heat pump is approximately four times higher than that of an average gas boiler, while the heat pump conversely has lower operating costs considering energy input, or more precisely the electricity the pump consumes (Calthrop, 2022). The decision of which heating option to utilize thus depends on the balance between the cost of electricity and the wholesale price of natural gas. For the heat pump to be the preferred option, it is necessary to demonstrate that the accumulated savings from investing in the electric heat pump, including the installment cost, result in lower expenses over an extended period, compared to the cost associated with the natural gas-based heater.

In 2020, the price of natural gas was at such a low level that the financial incentives to invest in electric heat pumps for domestic use were between low and non-existent. However, there were other reasons to invest in them, such as environmental friendliness. Even if electricity had been handed out at no cost at the time, the expenses of fossil fuel-based heating did not outweigh the capital investment of the heat pumps. Whereas, in 2023, with a gas price in Europe of EUR 150 per megawatts per hour (MWh), gas boilers quickly became much more expensive to operate, making investing in heat pumps the financially sound decision. The heat pumps would prove to be the be a wise investment, provided that the retail electricity price stay below EUR 475 per MWh (Calthrop, 2022). During 2022, the actual electricity price in European countries was EUR 235 on average, more than double the average price in 2021 (Kern et al., 2023), making a strong case for investment in heat pumps. For many households with solar rooftops and installed battery capacity, the electricity costs might be even lower, creating more advantageous conditions for investing in the electric heat pumps. Nonetheless, there can be other challenges associated with installment of heat pumps. Integrating heat pumps in existing properties often require supplementary investments in energy efficiency measures and may call for a switch to reliance on underground heating for optimal performance (Calthrop, 2022). Due to the increasing number of installment requests, particularly in Europe and Scandinavia, it has become challenging for many buyers to find heat pump installers in the imminent future, creating long lead times for delivery and installation (IEA, 2022c; Mathisen, 2022).

Comparably, the establishment of renewable energy power plants are viewed from a similar perspective: the initial investment associated with the construction of new plants, should be outweighed by the long-term economic benefits for governments and companies, in order to favor renewable energy sources over continued reliance on fossil fuels. The initial costs can

be a barrier for many households and businesses. The energy crisis has led to a surge in electricity prices, incentivizing the upfront costs of installing rooftop solar panels, in a similar way to the increased the financial incentives to invest in electric heat pumps. Several households, especially in Europe have recognized this and invested in rooftop solar panels to mitigate the high energy prices related to the energy crisis (SolarPower Europe, 2022).

Governmental support through various incentives and policies can help overcome the barriers of high initial cost and create favorable conditions for adoption of solar PV. The European Commission published the REPowerEU package as a response to the invasion of Ukraine with the roadmap for ending reliance on Russian fossil fuel imports. The European Green Deal and the REPowerEU aims to turn solar energy into a pilar of the European energy transition. The deployment has long been perceived as low hanging fruit, as solar energy systems have been a low-cost and reliable solutions for heating in European Countries. The main element to achieve widespread deployment of solar in Europe, is the solar mandate on all new public and commercial buildings of a certain size by 2026, existing buildings by 2027 and all new residential buildings by 2029 (European Commission, 2022). By providing financial incentives, such as tax credits or grants, this can significantly reduce the upfront costs, making solar panels more accessible and affordable for a broader range of the population. Leading to increased popularity of solar as a preferred solution for businesses and households in mitigating the energy prices, but also contribute to the broader energy security landscape. Support for uptake of rooftop solar panels can enhance domestic energy security by diversifying the energy mix, reducing dependence on imported energy sources and promote local energy production. Renewable energy technologies are favored when the conditions align in way that amplifies the economic benefits, such as during the energy crisis. The high energy prices combined with governmental support help the private sector to navigate the initial investments related to generation of solar energy.

Energy Security

The stability and security of energy supply are of outmost importance for nations. The energy crisis has highlighted energy security and the need to secure reliable and affordable energy. The approaches to mitigate the energy crisis should include measures that enhance not only energy security, but also facilitate the achievement of long-term environmental goals set for the next decades, such as increased use of renewable energy sources to generate power. This part of this text will address the implications the energy crisis has on the energy security, and measures and strategies that can be taken in response to the crisis in efforts to increase access and affordability, with an emphasis on solutions that has promoted the energy transition.

Understanding energy security

Energy security has long been a popular concept for policymakers and academics, especially in promoting policies or implementing changes. The term is regularly used in reference to secure access to sufficient supply of energy, and in discussions on geopolitics, climate change and energy governance. Commonly related to the term are uninterrupted access to energy, diversification of sources and supplies, resilience against external shocks and self-sufficiency (Thaler & Hofmann, 2021). Yet, energy security remains an elusive concept that is hard to firmly define despite the persistent and frequent use in discussions and literature (Ang et al., 2015; Chester, 2010).

This text will operate with energy security as a concept based on a definition made by Thaler and Hofmann (2021), used in their text on the energy trinity involving energy security, sustainability and sovereignty in multilateral electricity system. Their definition of energy security emphasizes the three dimensions: availability, affordability and accessibility. This definition based on specifically these three dimensions, reflect the core of the IEA's definition of energy security: "the uninterrupted availability of energy sources at an affordable price"(IEA, 2023b). In addition, the IEA highlight other aspects of energy security like those mentioned above, such as the long-term aspect of energy security, concerning policy changes and investments to supply energy in line with developments in the economic landscape and following changing environmental needs. On the other hand, there is the short-term aspect of energy security, which concerns a system's ability to react to and bounce back from external shocks. In the short-term aspect of energy security, there has been a lack of buffer to absorb the recent shocks, however, governments and private actors have responded to the stressors that came with the elevated energy costs. These actions influence the long-term aspect of energy security, shaping the preparedness and response mechanisms for future disruptions in energy generation and supply. It has also become evident that the focus on energy security and need to transition the energy sector are connected and can no longer be separated (Fucelli & Algeer, 2023).

The definition used by Thaler and Hofmann was chosen to better operate with the concept of energy security in a post-carbon era, taking height for renewable energy sources and electrification processes, in contrast with some definitions which mainly refer to energy security in relation to fossil fuels. Accessibility in Thaler and Hofmann's article is viewed as having "direct access to sufficient primary energy sources to meet demand" (Thaler & Hofmann, 2021, p. 2). Access is essential to be able to distribute energy domestically or locally, and an aspect of this is affordability which stresses the supply of energy at levels that are price competitive and attainable. Although, these dimensions require availability, the uninterrupted supply of energy to achieve energy security. This last aspect of availability gains relevance as renewable energy shares increase, due to the intermittency of these sources. Another challenge to ensure energy security is energy storage, as batteries and other solutions often are expensive and resource intensive. Acceptability is often referred to

as a fourth dimension of energy security, as the people's acceptance for energy source is a societal factor and increases regimes or business legitimacy. However, what is socially acceptable varies widely among groups and actors (Cherp & Jewell, 2014).

Public opinion or the publics acceptance of technologies and solutions can aid in expediting the energy transition. Policymakers pay attention to the public opinion, especially in democratic nations such as those found in Europe. However, for public opinion to have an impact, it must be accompanied by tangible action through the implementation of new policies. A study on changes in public support for clean energy policies recently conducted in Switzerland, found that people generally were more likely to say their support for these policies had risen rather than fallen as a result of the war (Steffen & Patt, 2022). Particularly, support for policies aimed at expansion of solar and wind capacity had the highest levels of support consistently across all political identifications. The respondents, collected to reflect the views of the Swiss population, expressed support for issues that would justify policy action taken, except installment of gas-fired power stations as a response to the energy crisis. It was further noted that these finding were likely to be similar throughout western European countries (Steffen & Patt, 2022).

The general opinion was found to support the reduction of fossil fuel-based solutions. The energy challenges were perceived to be stemming from a high dependency on fossil fuels, necessitating a solution that addresses the broader reliance on fossil fuels, rather than focusing solely on diversifying the sources of oil and gas imports. Moreover, the support of for policies aimed at accelerating the transition to renewables compared to the phase-out of fossil fuels, were higher, where one third of the respondents increased the level of support the past year. Additionally, the war and the following energy crisis, increased support for specific measures related to the roll-out of renewables, which previously have had less support (Steffen & Patt, 2022). Examples of these measures in the conducted study were ground mounted solar PV and support of wind turbines, which were controversial in Switzerland, indicating that in face of the energy crisis, people are more inclined to embrace measures that were previously met with skepticism or reservations.

The study attributed their findings of change in opinion to the fact that people are well-informed given the frequent debates on energy policy, rather than being entrenched in fixed political loyalty. This suggests an openness to reconsider opinions and adapting stance based on updated knowledge and new insights regarding the energy issue, which is promising for new policies on the matter, as there will be numerous new measures implemented in the coming years to both mitigate the energy crisis and to reach environmental targets associated with packages such as the REPowerEU and in relation to the Paris Agreement. Furthermore, the public support for implementing clean energy policies, enhances the government's legitimacy in taking steps that accelerate the transition towards renewable energies. This is in stark contrast to a scenario where public opinion favors increased import

of fossil fuels, which would impede the progress of the energy transition. In such a scenario, government's credibility could be at risk if they were to implement energy policies contradicting the will of the public. Therefore, the public's support for clean energy initiatives serves as an accelerating factor for the transition to renewables, given that policymakers follow up with the necessary policies, as has been the case in the past year with various new policies announced and implemented worldwide.

The socio-economic impact

Energy security plays a vital role in economic stability and growth, as seen in the energy crisis together with inflation and in some places, even economic recession. Industries and businesses rely on affordable and steady access to energy to thrive and operate efficiently and create overall economic productivity and increase value. When energy supply is disrupted or unaffordable, it heavily impacts economic activities. From an economic perspective, energy insecurity can be seen as a loss of welfare, from both the energy insecurities of cost fluctuations or the physical availability of energy (Bohi et al., 1996). A rise in energy prices can also lead to increases in unemployment due to rigid wages. Similarly, energy prices affect the capital markets through accelerated discontinuation or redundancy of productive capital, particularly for those that rely heavily on energy consumption (Labandeira & Manzano, 2012). The importance of energy security expanded considerably after the industrial revolution, due to the increase in intensive use of fossil fuels for energy generation. Since then, secure supply of energy has been strongly coupled with economic development. The energy crisis has highlighted the vulnerability of traditional energy systems and put energy security on the agenda. Ensuring energy security will continue to be an important issue as the world intends to transition to renewable energies.

Secure and affordable supply of energy is essential for the uninterrupted functioning of critical societal systems. In order to underline the challenges associated with energy security stemming from the energy crisis, it can be useful to look to one of the most important functions in society that needs consistent maintenance – namely, healthcare. The healthcare sector faces substantial stakes considering the escalated costs related to operating hospitals in general, encompassing important expenses such as wages, but also the provision of clean water supply and maintenance of sanitation. Ensuring that these functions operate properly is vital to society, as they are indispensable for upholding an efficient and safe healthcare system. Therefore, an energy crisis can lead to equipment failure, increased morbidity and mortality, elevated stress, decreases in overall performance and productivity in the institutions (Tsagkaris et al., 2023). In addition to inflation rates, production and transport costs have risen, including staff shortages and costs related to medical equipment. These factors have pushed hospitals to the verge of bankruptcy, and forced them to make some difficult decisions, like closing some of their care units.

Governmental institutions, such as hospitals, face challenges in adapting to escalating prices and inflation. “When you have a restaurant and your energy prices increase, you can increase the price of your products. So you can handle it, perhaps. But we can’t” said chief executive officer of the German Hospital Federation, Gerald Gaß, in an interview with Bencharif from Politico, representing all hospitals in Germany (Bencharif, 2022). According to the federation, hospital fees in Germany are calculated from two-year-old data, making it impossible for them to keep up with inflation. The combination of high energy costs and inflation poses a significant threat to the viability of the healthcare institutions. In the event of bankruptcy for the local healthcare providers, patients would have to travel long distances in order to receive care.

The German Health Minister, Karl Lauterbach, has been featured on the issue in numerous media outlets (Anadolu Anjansi, 2022; Pieper, 2022). Considering the magnitude of the energy crisis, it is likely that other European countries struggle with similar challenges. Conversely, some of the other member states have faced equally significant costs, but they may have benefitted from greater governmental support, which has increased their ability to manage the expenses. Another aspect of the high expenses that the hospitals contend with, is the hindering it poses for their ability to make necessary investments in infrastructure and technology. The financial constraints restrict their ability to distribute resources to facility upgrades and technological advances that are crucial to facilitate for improved healthcare services, but also upgrades related to energy efficiency and renewable energy utilization. (Belfius, 2022).

Consequences of high costs

When cost of energy is high, the three main aspects of energy security is threatened. Firstly, the access to sufficient sources of energy. For this aspect to be covered, or secured, there needs to be sufficient generation of power to be distributed. A prerequisite for this is abundance in multiple sources or singular source of energy. There have been sufficient resources to generate enough energy to meet demand, however, the access to the actual capacity is currently limited for the EU, as they have created a reliance on fossil fuel supplies from Russia. The cooperation and trade relation between Europe and Russia worked well until the last two years, when Russia began withholding and interrupting supplies, thus, threatening European energy security with lack of energy access.

The second aspect, availability, is impacted through disruption of existing infrastructure and trade necessary to distribute energy to Europe. After Russia invaded Ukraine, the EU responded by imposing sanctions against Russia including bans on Russian fossil fuel products. The measures were implemented with the purpose of weakening the financial capital used for warfare. The ban on Russian import has decreased the access to fossil fuel provisions in the EU, consequently increasing the price of oil and gas. The Russian restriction

of gas supplies in conjuncture with the European ban on Russian imports, have drastically curtailed the overall energy access needed in Europe to meet the regional energy demand.

The third, and perhaps most obvious aspect of energy security in the context of rising prices is affordability, meaning the access to energy at competitive price levels. Cost is a huge factor in accessibility, and has been a persistent concern, especially with inflation rates going up last year coupled with rising commodity prices. When energy prices, particularly the price of power, are at competitive levels, business and household have the economic capital to purchase and utilize electricity for daily activities and necessities. At unaffordable energy prices, the level of energy consumption is more likely to be insufficient to meet basic needs.

During 2022, there was a reversal in the trend of increased access to electricity. The number of people without access to electricity in general grew in 2022, turning a trend of increased access that has lasted for decades (Cozzi et al., 2022). Additionally, the number of people with access to clean energy decreased when the prices rose as 100 million people had to return to cheaper options such as fossil fuels and biomass for heating and cooking (IEA, 2022e). For households, increases in energy prices or living with lower income in times of increasing commodity prices can create difficult decisions regarding monetary spending. The households must then choose to either meet energy needs or prioritize other necessary expenses such as food and heating, which directly impact quality of life and even health of the affected individuals (Maxim et al., 2016).

Energy poverty poses a challenge in the wider socioeconomic context, as it not only reliable and steady energy supply matter for access to energy, but also the ability to purchase it. The lack of access to supplies of affordable energy undermines the notion of a just energy transition. Marginalized communities and low-income household may be disproportionately burdened by the rising costs, hindering their ability to participate in and even benefit from a transition to cleaner energy sources. Ensuring equitable access to affordable energy is a crucial requirement in promoting a just and inclusive transition, and furthermore, supporting a broad approach to address the energy transition as well as the aspects of energy security most related to energy poverty.

At a large scale, the EU has long had affordability and secure supply of energy as a priority for Member States, through regulations of the energy market, most of which associated with gas import. The EU has worked to achieve an integrated gas market internally, establishing a framework of cooperation and interconnectedness that can serve as a foundation for advancements with utilization of other energy sources. Solutions and strategies that promote cooperation like the those implemented by EU member states, are needed to address the challenges of energy transitions related to equitable access and enhanced energy security. Furthermore, this will shield against potential energy disturbances. The development of robust and strong interconnected grids like the European and ASEAN

countries are moving towards, holds great promise in regards to this (Fucelli & Algeer, 2023). Additionally, as the transition to renewables is quite extensive, there is a need to strengthen policy coordination to level out the imbalances in distribution of energy resources and secure affordable prices. Steffen and Patt (2022), conducted a study on the impact of the Russia-Ukraine war on public support for clean energy policies. Their findings revealed that support for policies aimed at expediting the clean energy transition could decline if the measures were perceived as leading to higher energy prices. In such a scenario, the economic challenges faced by households would be elevated, affecting not only those with lower income, but the overall population.

Increasing energy security

The geopolitical tensions and energy crisis have, in a sense, fostered a positive outlook for the energy security, economic development and environmental sustainability. The new landscape carved by the energy crisis has reduced the prominence of certain tradeoffs connected to the energy transition. Previously, there were stronger incentives to favor fossil fuel sources due to their perceived reliability and lower cost compared to renewable energies. However, the current energy crisis has shifted the energy landscape, and diminished these factors, emphasizing the urgency of ensuring energy security and economic resilience, while prioritizing long-term energy security and sustainability. As a result, nations are taking action to enhance their energy security aligning with climate targets and sustainable development goals, including increased deployment of renewable energy technologies. Below are some of the challenges and solutions implemented to improve energy security in times of uncertainty, as the ongoing energy crisis.

To achieve the highest level of energy security and resilience, the most optimal situation a country could be in would entail a reliance solely on domestic energy sources and production to cover the national demand. This would necessitate an installed capacity exceeding day-to-day energy demand, allowing for a buffer to accommodate increased demand and cover consumption peaks. The higher a country's dependence on import, the more susceptible it becomes for geopolitical tensions and economic risks. There are numerous strategies countries can utilize in efforts to increase or achieve energy independency.

The above-mentioned aspects of energy security feed into the strategies to address energy security, as these are actions that countries can undertake to ensure availability, affordability and access to energy. Energy security entails ensuring resilience and robustness of the energy system in the face of challenges and disruptions. This can be accomplished through reducing dependency on import, cooperative efforts, diversifying energy supplies, and improving efficiency to minimize unnecessary energy consumption. Additionally,

investments in smart infrastructure and advanced storage solutions are crucial for strengthening of energy security in combination with renewable energies.

The strategies implemented by countries to enhance energy security can be regarded as measures to tackle the energy crisis. This, in turn, stimulate a discussion surrounding the acceleration of an energy transition towards renewable energy sources. Certain measures aimed at strengthening energy security in the short-term have been fossil fuel based, given their widespread usage and the well-established energy systems that rely on these fuels. On the other hand, several of the implemented measures addressing the energy crisis, promote a transition towards renewable and more sustainable energy sources in the long term. The pressing need to tackle the reliance on fossil fuels and address environmental concerns are growing. It is expected that the measures implemented in response to the energy crisis will aid the adoption of cleaner and sustainable alternatives, leading to a more resilient and environmentally friendly energy future.

Self-sufficiency and domestic resources

The first strategy to enhance energy security involves strengthening self-reliance through the country's own energy resources. Now that the Western trust in Russia is broken, Statkraft, the Norwegian state-owned energy giant and leading European generator of renewable energy, states that energy self-sufficiency has entered the top of the policy agenda (Statkraft, 2022a). Notable illustrations of high degrees of self-sufficiency can be seen in the country of Norway and in Iceland, as their power supplies are predominantly generated from hydropower plants. This production constitutes more than 85% of primary energy supply in Iceland, and roughly 90% of the power production in Norway (Statkraft, 2022b). By harnessing domestic renewable energy source, these counties effectively meet their energy needs while reducing dependence on external sources in the form of energy imports. Norway also has a relatively high exploitation of fossil fuels resources which in conjuncture with the hydropower capacity amount to a strong energy independence. The country exports energy to other nations through subsea gas pipe infrastructure to both the UK and the continental Europe to Germany, Belgium and France (Ministry of Petroleum and Energy & The Norwegian Petroleum Directorate, 2022).

Reduction of demand

Measures to reduce energy demand are a big part of strategies to increase energy security in response to the energy crisis. Countries can increase energy self-sufficiency through reducing domestic demand for energy. Energy efficiency can play a big role in meeting energy needs, as energy efficient solutions can do more work for less energy input, while also freeing up energy to promote other objectives. To achieve this goal, countries can implement national policies encouraging cycling or public transport instead of driving.

Additionally, granting subsidies towards increased energy efficiency in buildings, through measures like insulating or retrofitting of houses can contribute to the desired outcome of reducing energy consumption. Other, more complex means for optimizing energy efficiency involve utilization of digital and technological advances to a greater extent. For instance, the deployment of smart grid systems can significantly contribute to an increase of energy efficiency and energy security across various sectors. These grids coordinate the capabilities of energy generators, grid operators, electricity market stakeholders and the needs of end users to optimize the system, with generation and distribution as efficiently as possible. This type of technological tools and approaches unlock opportunities to further improve energy efficiency, as they aim to reduce energy losses and wastages, with saved costs and coordinated energy generation to minimize environmental impact (IEA, 2022b). Energy efficiency measures play a crucial on the path to maximize system flexibility, stability and resilience, which is particularly important in setting the stage for a transition to renewable energy sources.

The United States, Europe and various countries around the world have implemented various measures to conserve energy and reduce demand in the short, medium, and long term. One of the European initiatives requires Member States to achieve a 5% reduction in peak electricity consumption, including an additional voluntary expansion to a 10% reduction from December 2022 to early 2023 with the possibility of extending this commitment (Widuto, 2023). Energy efficiency is a key focus in Europe, as demonstrated by the REPowerEU proposal, aiming to increase the 2030 energy efficiency target by 13%, an additional 9% increase from the proposal in the European Green Deal and “the Fit for 55” package (Widuto, 2023). Moreover, this legislative proposal involves amendments to the Energy Performance of Buildings Directive, mandating the installation of solar PV systems on public and residential buildings in Member States. In a policy brief for Bruegel, McWilliams and his colleagues (2023) recommend that the EU should prolong demand reduction measures and targets to at least October 2023 to dampen the crisis and promote energy security in the short-term, as it was set to expire at the end of March 2023.

Diversification

An important aspect of ensuring energy security is diversification. One effective strategy in diversifying energy sources is through import from a wide range of suppliers. The presence of multiple energy sources provides the advantage of being able to switch between suppliers when the international political landscape changes. Additionally, diversification of sources allows for greater pricing and competitiveness among suppliers, considering the availability, cost of necessary resources, technological advances, varying taxes and subsidies, as well as weather and climate occurrences that can hinder energy transport. Utilizing this approach mitigates the risks of overreliance on a single supplier, increasing the resilience to supply disruptions, thus enhancing overall energy security.

As response to the energy crisis, countries rushed to diversify their energy supplies outside of Russia to ensure supply of energy. Although not directly related to the energy crisis, Japan serves as a prime example of diversification of suppliers, given its relatively low degree of energy self-sufficiency due to scarce domestic natural sources (Japanese Agency for Natural Resources and Energy, 2022). Japan produced energy domestically for a while by utilizing nuclear technologies to generate power. However, due to the country's history of nuclear power, such as the Fukushima nuclear disaster and public opinion on the technology, nuclear power production has decreased over time. According to the Japanese Agency for Natural Resources and Energy, the country had a self-sufficiency rate of just over 12% in 2019, with one portion of domestic production coming from nuclear power and the other from renewable sources. For this reason, Japan depends heavily on imports to meet energy demand. The country has actively pursued diversification of energy sources by relying on deliveries from various exporters, with more than five countries supplying fossil fuels. Notably, Japan is a huge importer of crude oil from countries in the Middle East and LNG from Asia and Oceania (Japanese Agency for Natural Resources and Energy, 2022).

Another approach to enhancing energy security through diversification is through the incorporation of various energy sources in the energy mix. Japan imports energy supplies from various sources, yet, in a case of fossil fuel shortage or energy crisis like the one happening at the time of writing, countries with a high dependency of fossil fuels in their established energy systems are vulnerable. To mitigate the risks associated with the energy crisis and reliance on a limited number of energy sources, like a significant dependency on fossil fuels or nuclear, it is crucial to diversify not only the sources, but the entire energy mix. To achieve this, it is necessary to have flexible solutions in place to address scarcity of specific energy commodities.

Flexibility enables the system to adjust to changing demands and conditions, ensuring a reliable energy supply that enhance the energy security and resilience. Diversifying energy sources by implementing renewable energy solutions, countries enhance the flexibility needed to adjust to changing demands and conditions of the ongoing and future energy crisis. This benefit of flexibility as well as the ability to generate energy from other sources than Russian fossil fuels, has been widely recognized worldwide during the energy crisis. The World Energy Outlook and the reports examined in this thesis consistently acknowledge the advantages renewable energy sources in enhancing domestic and regional energy security. The policies such as the Inflation Reduction Act and the REPowerEU, exemplify efforts undertaken by countries, particularly the US and the EU to implement these technologies, driven by the aim of improving energy security.

Cooperation and partnerships

The establishment of reliable partnerships with supplier nations is another approach to bolster energy security. High reliance on import can often indicate a vulnerability regarding energy security, although, this can be made less vulnerable through close cooperation with countries that supply energy, with an emphasis on reliable supply. An example of integrated energy networks is the cooperation between the USA and Canada, which co-supply each other with electricity from different sources of energy (U.S. Energy Information Administration, 2021). Another example of this is the integrated trading system within the EU, which has mainly built an internal infrastructure for trade and distribution of gas supplies. An integrated electricity grid facilitate for system resilience by offering market balance and higher degree of flexibility at a lower cost compared to each nation investing in the domestic options (Thaler & Hofmann, 2021). Cooperation across borders also enable a more diverse set of renewable energies and improve countries' position concerning investments in infrastructure and balancing the system.

Integrated systems

A transition to renewable energies would require an upgrade in energy systems and integrated solutions that cross national borders. An aspect of energy security regarding renewable energies is geographical diversification to bolster energy security. Because the generation of energy using renewables can be more volatile than fossil fuels, energy systems need to be diversified and preferably spread in different geographical locations to compensate for the fluctuations of renewable energy production and secure available energy supplies even when the sun is not shining, and the wind is calm. Cooperation across borders enable a more diverse set of renewable energies and improve countries' position concerning investments in infrastructure and balancing the system. An integrated electricity grid enhance system resilience by offering market balance and higher degree of flexibility at a lower cost compared to each nation investing in the domestic options separately (Thaler & Hofmann, 2021). Additionally, upgrades of the existing grids are paramount to effectively deploy renewable energy technologies, as ensuring distributing can be as important as energy supply.

As all 27 Member States of the European Union are net importers of energy sources, the region is highly dependent on energy supplies to maintain energy security and steady domestic distribution (Widuto, 2023). There has been considerable progress in the efforts to achieve energy security together with independence from Russian fossil fuels. Most important of these measures are the steps to increase diversification of energy import suppliers, filling up gas storages, increase energy efficiency and reduce energy demand, together with an increased deployment of renewable energies. Still, energy security is a concern as there is an estimated shortage of almost 30 billion cubic meters of natural gas heading into the next winter season in 2023. The contributing factors for this shortage are

phasing out of Russian supplies in the EU, unfortunate weather conditions that affect electricity generation and a rebound in Chinese LNG demand due to industrial uptake (IEA, 2023a).

In response to the energy crisis, the EU has undertaken measures to mitigate its effects, including the implementation of new policy strategies, the adaptation of regulations, and the revision of energy directives (Widuto, 2023). One significant initiative is the REPowerEU project, which was published with the aim of improving energy efficiency, reducing energy demand, promoting renewable energy sources, and diversifying energy supplies. The EU is looking to diversify its energy supply by increasing imports from countries such as Norway, the United States, and Qatar (Widuto, 2023). Traditional suppliers to the EU, such as Algeria, Azerbaijan, and the United Kingdom, continue to play a role as well. However, the development of new liquefied natural gas (LNG) infrastructure has faced challenges due to uneven distribution of LNG terminals and a lack of interconnections across Europe (EPRS, 2022).

To ensure a balance of affordability, security and sustainability for future energy, in an article written for the World Economic Forum connected to the annual meeting in Davos, Fucelli and Algeer express that the energy crisis should not lead to increase investment in infrastructure connected to coal and that new gas infrastructure should align with low carbon goals. Pipe infrastructure intended for use with gas should be designed to be able to transport hydrogen in the future and be leakage-proof to ensure longevity of the pipelines. Furthermore, they emphasize that investments should address the need for development within renewable energies and ensure available low-carbon energy sources and diversified fuels in the energy mix (Fucelli & Algeer, 2023)

Storage solutions

A fourth strategy to increase energy security is through reliable storage solutions that can balance the grid in smaller and bigger demand peaks and fluctuations. There are multiple storage systems that depend on different technologies to operate. For the purpose of this thesis, it is not necessary to go in depth on these systems , although, it is important to note that there are different ways to store energy. One of the most common and well-established storage solutions is pumped hydroelectric storage, where water is kept in a reservoir and then released when there is a need to generate more electricity. Another popular form of energy storage is thermal systems, as hot or cool air is stored to either generate electricity through thermal energy or used for heating or cooling purposes. Electrochemical storage solutions such as batteries, have increased in popularity the past few decades, although they have been valued for their properties to store energy for multiple decades. Batteries are widely utilized in the expansion of renewable energies and electronification of technologies, such as electric vehicles (EVs). A fourth way to store energy is called “power to gas”, which

allows for energy to be stored and transported as gas rather than through electricity grids for immediate consumption. The most used gases are either LNG or hydrogen. This is one of the most utilized storage solutions as the power to gas system enables large scale storage for long periods of time and has proven to be a good storage solution for seasonal storage.

Energy storage will be important to achieve a high degree of energy security in Europe throughout 2023. According to a policy contribution made for Bruegel by McWilliams et al. (2023), gas storage facilities should be filled to at least 90% by October 1st 2023. There are some concerns about achieving this, one of them related to competition for limited LNG in the global market, and another concern is aimed at the capacity of the European import infrastructure, which is addressed through swift deployment of regasification infrastructure (McWilliams et al., 2023). This signifies intentions to uphold the reliance on fossil fuels, rather than accelerating the transition to renewables energies. Although, as previously mentioned, gas infrastructure can be designed for future transport of hydrogen, a gas which is a more sustainable energy source compared to LNG. The importance of storage has long been a pressing challenge related to reliance on renewable energy sources. Advancement in technology and innovation are constantly being developed to address this challenge. The Energy Storage Coalition, founded in 2023, is an organization dedicated to aid the decarbonization of the European energy system by increasing the storage solutions to support renewable technologies. The establishment of coalitions such as this demonstrate promising progress in facilitation for the widespread adaptation of renewable energy sources.

Conclusion

Within the energy crisis, the world is at a crossroads that holds the potential to reshape the energy system. Addressing the energy crisis requires a comprehensive approach, entailing parallels to measures that accelerate the energy transition. This includes diversification of the energy mix, the promotion of energy efficiency, investments in renewable and sustainable energy sources, improving energy infrastructure and encouraging international cooperation. The critical juncture presents a remarkable opportunity to expedite the transition to renewable energy sources. It is important to make it clear that the energy transition is expected to be complex, and even though it has been accelerated by the energy crisis, the context has further complicated the pathway (Calthrop, 2022; IEA, 2022e).

Incentives for deployment of renewable energy technologies are strong when the conditions amplify the economic benefits, as seen during the energy crisis. The policy response in addition to elevated energy prices create advantageous conditions for the private sector to invest in renewable energy solutions, with a particular uptake in wind and solar power generation. By leveraging these opportunities, businesses and individuals can navigate the

initial costs and harness the economic advantages of renewable energy while contributing to a more sustainable and resilient energy system.

The urgent need to accelerate the transition to renewable energy is driven by several effects stemming from the energy crisis. One of major influences is the mounting geopolitical pressure caused by the invasion of Ukraine, resulting in inflation and high commodity prices, particularly for power and fossil fuels. To effectively tackle these challenges and support the transition to a more sustainable energy future, significant investments need to be made across diverse energy value chains. Notably, even with an increase in the investment levels for solar and wind capacity, that reflect a growing recognition for the importance of renewable energy sources. These investments need to be elevated considerably compared to investment levels made in recent years, in order to make substantial progress towards achieving renewable energy goals at the national and regional level. While the demand for fossil fuels is currently on a declining trajectory, continued investment in oil and gas remains necessary for a successful transition process.

Contrary to some conceptions, the energy crisis should not be perceived as a major setback in addressing climate change. The current situation can serve as a pivotal moment in the transition towards renewable energy sources, among other important steps towards net-zero emissions systems, largely due to the unprecedented response from governments worldwide. Throughout this thesis, extensive research has been conducted, drawing upon publications by reputable global agencies, such as the World Energy Outlook by the International Energy Agency (IEA), reports by the International Renewable Energy Agency (IRENA), as well as a wide range of articles, reports and governmental resources. The examination of key policies such as the American Inflation Reduction Act and REPowerEU in the European Union, supports the assertion that the urgency created by the energy crisis has driven governments to take actions towards cleaner energy source. The findings presented in this thesis form a compelling argument, highlighting that the energy crisis, triggered by the Covid-19 pandemic and the Russia-Ukraine war, has accelerated the transition towards renewable energy sources.

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